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6. AUTHORS

Xiaoli Ma

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14. ABSTRACT

During the project period, the PI and one graduate research assistant have conducted extensive research guided by the proposal that we submitted. Three main objectives are achieved: (1) thoroughly studied the fundamental limits of low complexity decoder; (2) proposed differential decoder based timing synchronization method; and (3) designed turbo decoders to enhance the receiver performance. Supported by this project, 7 journal papers and 10 conference proceeding papers have been published/submitted, and collaborations with ARL and defense industry (General Dynamics) have been established. In addition, during this period, new ideas and approaches along this topic have emerged to better finish up the rest of the project

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Report Title

A Study on Trained and Differential Designs for MIMO Tactical Communications

ABSTRACT

During the project period, the PI and one graduate research assistant have conducted extensive research guided by the proposal that we submitted. Three main objectives are achieved: (1) thoroughly studied the fundamental limits of low complexity decoder; (2) proposed differential decoder based timing synchronization method; and (3) designed turbo decoders to enhance the receiver performance. Supported by this project, 7 journal papers and 10 conference proceeding papers have been published/submitted, and collaborations with ARL and defense industry (General Dynamics) have been established. In addition, during this period, new ideas and approaches along this topic have emerged to better finish up the rest of the project period and develop continued proposal for possible future funding.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

[1] S. Zhou, X. Ma and K. Pattipati, "A view on modulus-preserving rate-one space time block codes," Signal Processing, Aug. 2006.

[2] X. Ma and W. Zhang, "Performance analysis for V-BLAST systems with lattice-reduction aided linear equalization," IEEE Trans. Communications, vol. 56, no.2, pp. 309-318, Feb. 2008.

[3] W. Zhang, F. Arnold, and X. Ma, "An analysis of Seysen's lattice reduction algorithm," Signal Processing, May 2008.

[4] X. Ma and W. Zhang, "Fundamental limits of linear equalizers: diversity, capacity and complexity," IEEE Trans. Information Theory, Aug. 2008.

Number of Papers published in peer-reviewed journals: 4.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals: 0.00

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

[1] W. Zhang and X. Ma, "Quantifying diversity for wireless systems with finite-bit representation," Proc. International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Las Vegas, NE, Mar. 30 – Apr. 4, 2008.
[2] J. Kleider, G. Maalouli, and X. Ma, "Timing synchronization in distributed mobile MISO Rayleigh fading channels," Proc. IEEE Military Communications Conference, Orlando, FL, Oct. 29-31, 2007.
[3] W. Zhang, X. Ma, and A. Swami, "Designing soft detectors based on Seysen's algorithm," Proc. IEEE Military Communications Conference, Orlando, FL, Oct. 29-31, 2007.
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[5] W. Zhang and X. Ma, "What determines the diversity order of linear equalizers?," Proc. International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Honolulu, HI, Apr. 15-20, 2007.
[6] W. Zhang and X. Ma, "Approaching optimal performance by lattice-reduction aided soft detectors," Proc. 41th Conference on Information Sciences and Systems, Johns Hopkins University, MD, Mar. 14-16, 2007.
[7] X. Ma, R. J. Baxley, J. Kleider, and G. T. Zhou, "Superimposed training for channel shortening equalization in OFDM," Proc. Milcom, Oct. 23-25 2006.
[8] W. Zhang, X. Ma, and A. Swami, "Maximum diversity of MIMO-OFDM schemes with linear equalizers," Proc. 4th IEEE Workshop on Sensor Array and Multi-channel Processing (SAM), July 2006.
[9] A. Cano, X. Ma, and G. B. Giannakis, "Space-time differential modulation using linear constellation precoding," Proc. International Conference on Communications, Istanbul, Turkey, June 11-15, 2006.
[10] J. Kleider and X. Ma, "Adaptive channel shortening equalization for coherent OFDM doubly selective channels," Proc. International Conference on Acoustics, Speech, and Signal Processing, Toulouse, France, May 15-19, 2006.

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 10

(d) Manuscripts

[1] W. Zhang, X. Ma, and A. Swami, "Designing Low-Complexity Detectors Based on Seysen's Algorithm," IEEE Trans. Wireless Communications, submitted Apr. 2008, revised Sept. 2008.

[2] W. Zhang and X. Ma, "Low-complexity iterative decoding with lattice-reduction-aided detectors," IEEE Trans. Communications, submitted Dec. 2007, revised Oct. 2008.

[3] X. Ma, W. Zhang, and A. Swami, "Lattice-reduction aided equalization for OFDM systems," IEEE Trans. Wireless Communications, submitted Sept. 2007, revised Dec. 2007 and Sept. 2008.

Number of Manuscripts: 3.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
Wei Zhang	0.80
Felix Arnold	0.20
FTE Equivalent:	**1.00**
Total Number:	**2**

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Project Report

Title: A Study on Trained and Differential Designs for MIMO Tactical Communications
Grant Number: W911-NF-06-1-0090
Time Period covered by this report: 04/06/06-04/05/08
PI: Xiaoli Ma, School of ECE, Georgia Institute of Technology

1. Approaches and Scientific Barriers

- *Timing synchronization based on differential detector and power allocation*

  We propose a novel acquisition technique to improve single-antenna receiver detection performance of signals from multiple transmitters that are distributed spatially.
  We assume that the distributed transmissions occur simultaneously, but the start time of each of the respective transmissions are not synchronous due to imperfect coordination and non-synchronized clocks across distributed transmitters. First, we propose a robust combining method in mobile channels when there is no feedback or channel knowledge between the receiver and the distributed transmitters. Next, we propose a power control technique, given feedback (and partial channel knowledge) between the receiver and distributed transmitters, to improve the receiver operating characteristic (ROC) performance when re-acquiring multiple distributed transmitters. The ROC performance improvements are demonstrated for multiple distributed transmitter signal detection in a mobile Rayleigh fading channel. Analytical solutions are derived to predict the ROC performance when no channel knowledge is assumed, which is corroborated via simulation. For the power control method, simulation is used to demonstrate performance improvement (over the no feedback case) when the channel is estimated with error and feedback latency. The probability of missed detection is improved by at least a factor of 10 and 100, respectively.

- *Lattice reduction aided turbo detectors*

  Lattice reduction (LR) technique has been applied onto linear equalizers to improve their performance. Two major low-complexity LR methods are Seysen's algorithm (SA) and the well-documented LLL algorithm. However, most of the existing methods on SA and LLL are making hard decision which is know with suboptimal performance. When error correcting code is applied, soft detectors naturally come into picture and composite turbo detector. In this period, we first develop a tree-search implementation for SA, which reduces the complexity of SA without sacrificing its performance. Based on this algorithm, an LR-aided soft detector is proposed to achieve better performance. The performance-complexity tradeoff of our proposed algorithms is also studied. We also developed three LLL-based soft detectors with different candidate generation methods. We compare the performance and complexity of our algorithms with the existing alternatives and show that our methods can achieve near-optimal performance. The performance-complexity tradeoffs of our proposed algorithms are also studied. Simulation results validate the effectiveness of our algorithms.

- *Fundamental Limits of Linear Equalizers: Diversity, Capacity and Complexity*

Linear equalizers (LEs) have been widely adopted for practical systems due to their low computational complexity. However, it is also well-known that LEs provide inferior performance relative to maximum likelihood equalizer (MLE) or other near-MLEs, e.g., Les usually can not collect the diversity order enabled by the transmitter and at the same time they lose mutual information. More important, unlike MLE or near-MLEs, the performance of LEs has not been well quantified. This hinders more generalapplications on LEs in wireless systems. In this period, we reveal a fundamental link between a channel parameter – orthogonality deficiency (od) of channel matrix -- and the diversity and capacity of LEs. We identify that when the od of channel matrix has an upper bound strictly less than 1, the same diversity order as that of MLEs is collected by LEs and the outage capacity loss relative to MLEs is also a constant over SNR. These results can be applied on the design of an analytical framework of hybrid equalizers. Furthermore, by studying the statistical property of the od and comparing the complexity of different equalizers, we show that the hybrid equalizers can tradeoff the performance and complexity by tuning the channel matrix od. The theoretical analysis is corroborated by computer simulations.

2. Significance

In future army wireless communications and networks, it is critical to develop signal processing methods to support high spectral efficiency, high transmission rate, low decoding delay, and high mobility for war-fighters on-the-move, secure anti-jam links, and reduce the probability of interception and detection. MIMO systems provide great potential along these lines. OFDM is an attractive transmission technique for terrestrial communications because of its robustness and spectral efficiency in multi-path channels. However, in some multi-path channels, which are commonly encountered in battlefield communications, improved efficiency is needed due to excessively long delay spreads in the channel. Moreover, mobile operation requires robust operation as channel conditions vary over time. The focuses of this project are military-related aspects; e.g., LPD/LPI, anti-jamming, latency/delay, MAI, NLOS fading, and robustness to synchronization errors. We will further improve efficiency of transmissions in mobile channels by developing adaptive channel shortening techniques. Furthermore, extended robustness will be achieved by utilizing iterative and multi-dimensional demodulation techniques at the receiver. Low complexity solutions are achieved using differential modulation / demodulation, which is significant for small form factor communication devices such as handheld, manpack, and sensor radio nodes.

3. List of Publications (April 2006- April 2008)

[1] W. Zhang and X. Ma, "Quantifying diversity for wireless systems with finite-bit representation," Proc. International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Las Vegas, NE, Mar. 30 – Apr. 4, 2008.

[2] J. Kleider, G. Maalouli, and X. Ma, "Timing synchronization in distributed mobile MISO Rayleigh fading channels," Proc. IEEE Military Communications Conference, Orlando, FL, Oct. 29-31, 2007.

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[12] S. Zhou, X. Ma and K. Pattipati, "A view on modulus-preserving rate-one space time block codes," Signal Processing, Aug. 2006.

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[15] X. Ma and W. Zhang, "Fundamental limits of linear equalizers: diversity, capacity and complexity," IEEE Trans. Information Theory, Aug. 2008.

[16] (**book chapter**) X. Ma and G. B. Giannakis, “Space-time coding for time-selective and frequency-selective MIMO channels,” in H. Bolcskei, D. Gesbert, C. Papadias, and A. J. van der Veen, editors, *Space-Time Wireless Systems: From Array Processing to MIMO Communications*, Cambridge University Press, 2006.

[17] (**book**) G. B. Giannakis, Z. Liu, X. Ma, and S. Zhou, *Space-Time Coding for Broadband Wireless Communications*, John Wiley & Sons, Inc., 2006 (to appear).

4. Collaborations

The PI has ongoing collaborations with defense industry (General Dynamics, Telcordia) on MIMO differential designs and OFDM filter design topics, and Army Research Lab (Dr. A. Swami) on low-complexity decoding method. The PI also has collaborations with other Army funded projects, for example, with Georgia Tech (Dr. G. T. Zhou) and University of Minnesota (Dr. G. B. Giannakis).

5. Technology transfer

- The PI participated and presented research results at ARL/CTA annual review in March 2006, May 2007, May 2008.
- Collaborations have been built with General Dynamics which is in defense industry (see joint publications [2], [7], [10] and [11])
- Collaboration has been built with ARL (see joint publication [3], [8] and others under review)
- Computer codes from this project have been transferred to General Dynamics and ARL for possible testbed implementation

6. Conclusions

During the project period, the PI and one graduate research assistant have conducted extensive research guided by the proposal that we submitted. The proposed objectives for this year have been achieved, 7 journal papers and 4 conference proceeding papers have been published/submitted, one MS degree is awarded, one book is published and collaborations with ARL and defense industry have been established. In addition, during this period, new ideas and approaches along this topic have emerged to better finish up the rest of the project period and develop continued proposal for possible future funding.